Thermal photons and dileptons: where do we stand?

And where do we want to go?

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Disclaimer:

The views expressed are **solely mine**. Not those of PHENIX, the Physics Department, BNL, the Tea Party, the fairy grandmother, etc.

"Anybody saying otherwise is itching for a fight" [NPR 172 (2011) 1200]

Context and ideal outcome

Long-range upgrades of RHIC detectors vigorously planned
→ CD0 expected in less than a year

Thermal photons and dileptons are not a prime physics goal in those plans
→ contrast this to the planning stage 20 years ago

Such shift may be justified, but if so, let's discuss it explicitely, why

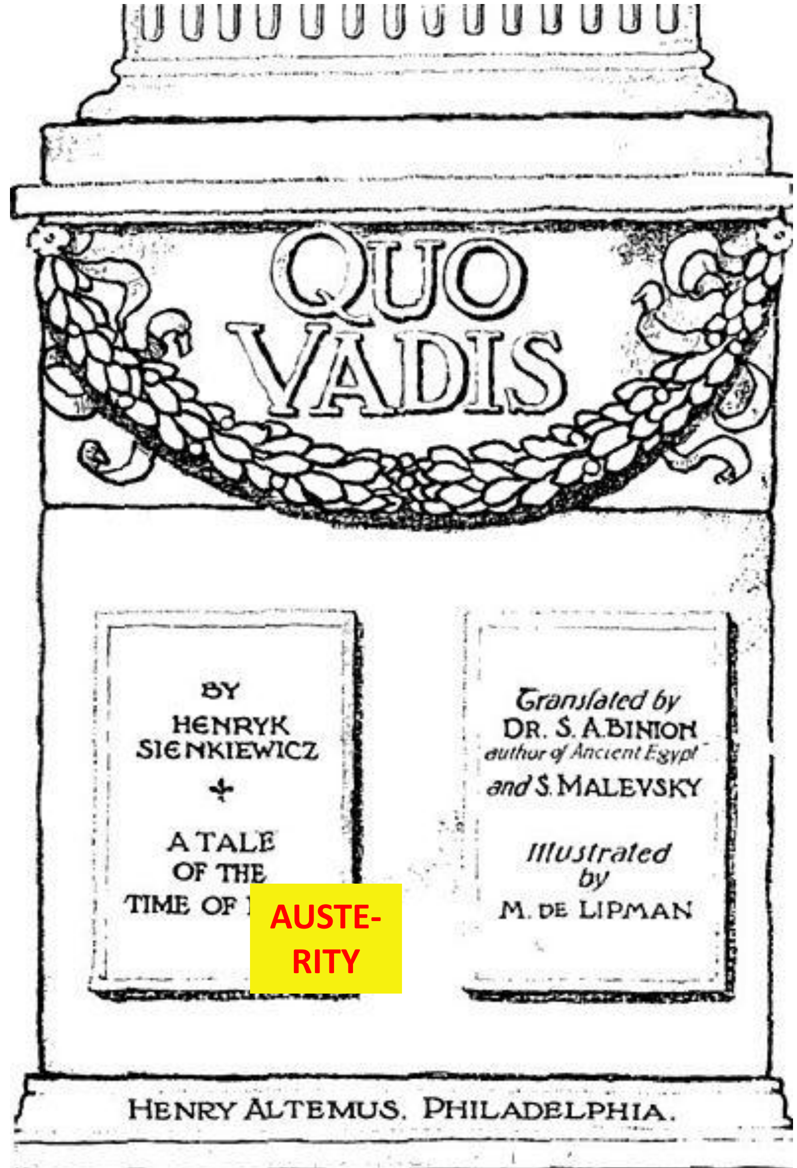
IF we find that thermal photons are still of paramount importance, let's start
→ building strong **support** to keep a **strong** thermal photon/dilepton **program**
→ forming a **dedicated working group** (exp, theory) for the next 6-8 months
→ producing a document that makes the **physics case** and shows realistic ways to achieve it.

In doing so let's concentrate on what is

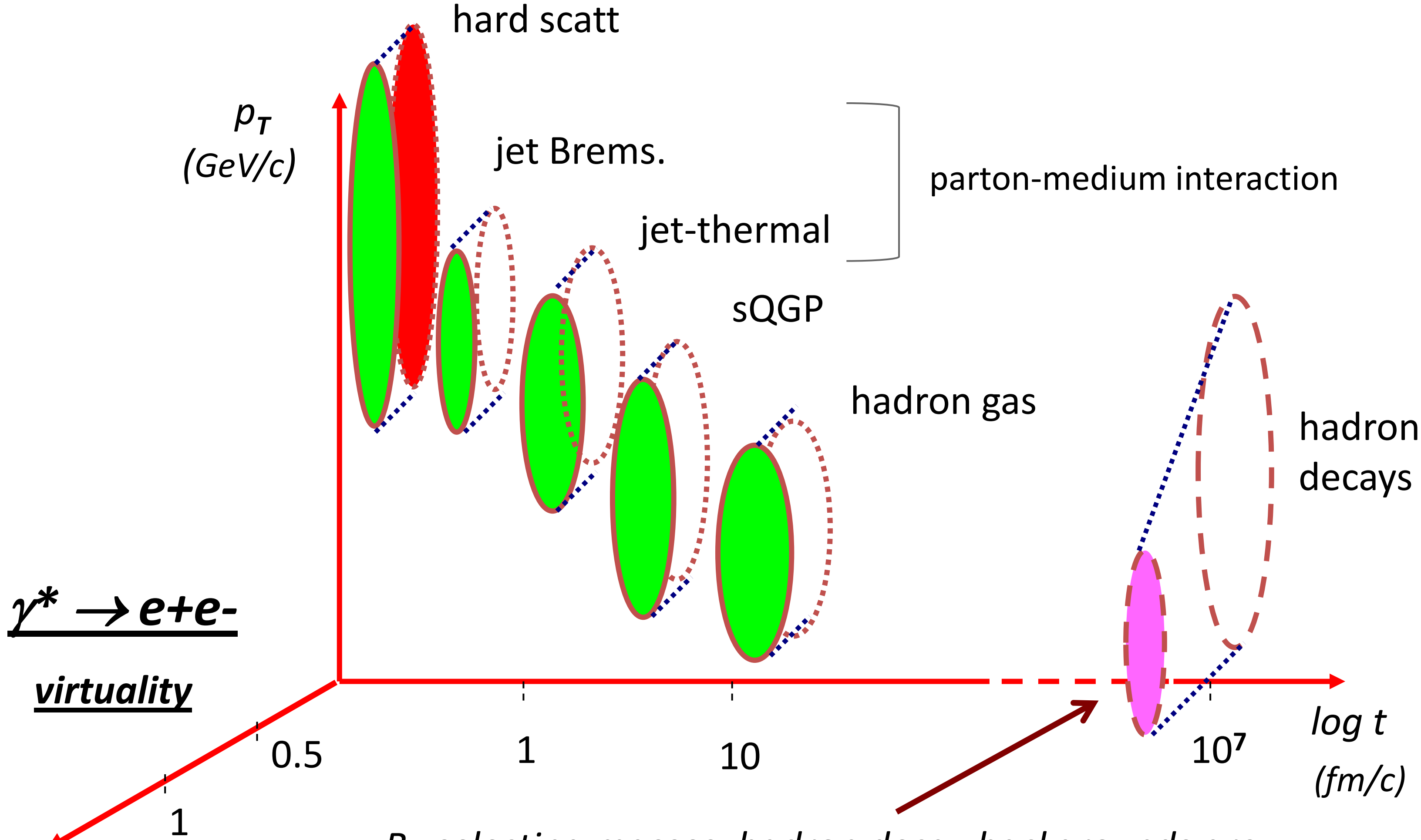
Really interesting? What observable?
Decisive (and at what significance)?
Feasible (technology, funding)?

In other words: QUO VADIS, thermal photons?

(Remember:
about 25 years ago besides J/Psi thermal photons were the "surest" signal and diagnostic tool of the Quark-Gluon Plasma)



Then what's wrong with this picture?



By selecting masses, hadron decay backgrounds are significantly reduced. (e.g., $M>0.135GeV/c^2$)

Timeline / lessons learned

~1978 - ~1992 → QGP thermal radiation is obviously overwhelming…

~1992 - ~2010 → QGP thermal radiation dominates in a pT window…

Nowadays → uhm, is there a "QGP window" at all?

Both the measurements and the theory are quite involved (read: hard)
→ case in point: time-lag between data taking and completed analysis

Looking for small variations of small signals in huge background
→ multiplicity, $\alpha_{em} << \alpha_s$

No clear "factorization" of sources (mechanisms)
→ although dileptons (with additional d.o.f. may differentiate between partonic and hadronic sources)

Selected results – and issues

I'm not going to give a complete review of results and issues (far from it!)
→ we have many talks by experts to do this

Just show a few examples of triumphs and puzzles
→ to make the point why in my mind this field is still wide open
(and more interesting than ever)

Who is "ahead" (theory? experiment? in what?)

Really interesting? What observable?
Decisive (and at what significance)?
Feasible (technology, funding)?

Thermal photons, SPS – WA98, calorimetry

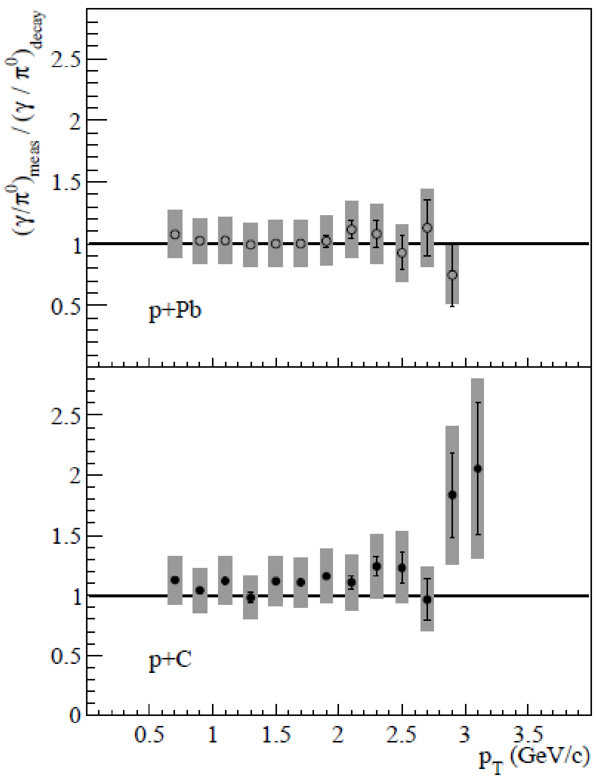


FIG. 4: Double ratio $R_\gamma = (\gamma/\pi^0)_{meas}/(\gamma/\pi^0)_{decay}$ for p+Pb (upper panel) and p+C (lower panel) collisions at $\sqrt{s_{NN}}$ = 17.4 GeV. A fit to the neutral pion data from [18] has been used for the measured π^0 result. The error bars show the statistical errors and the shaded areas show the systematic uncertainties of the measurements.

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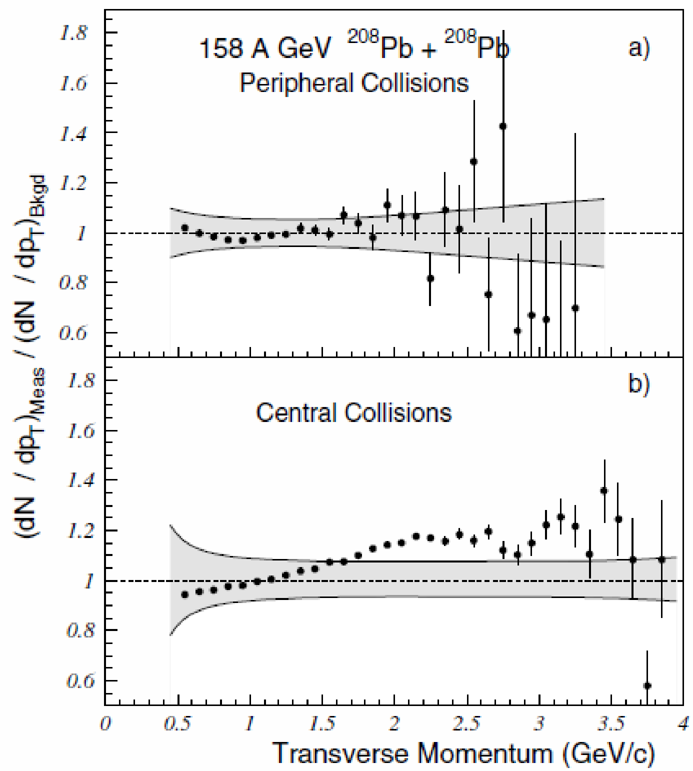
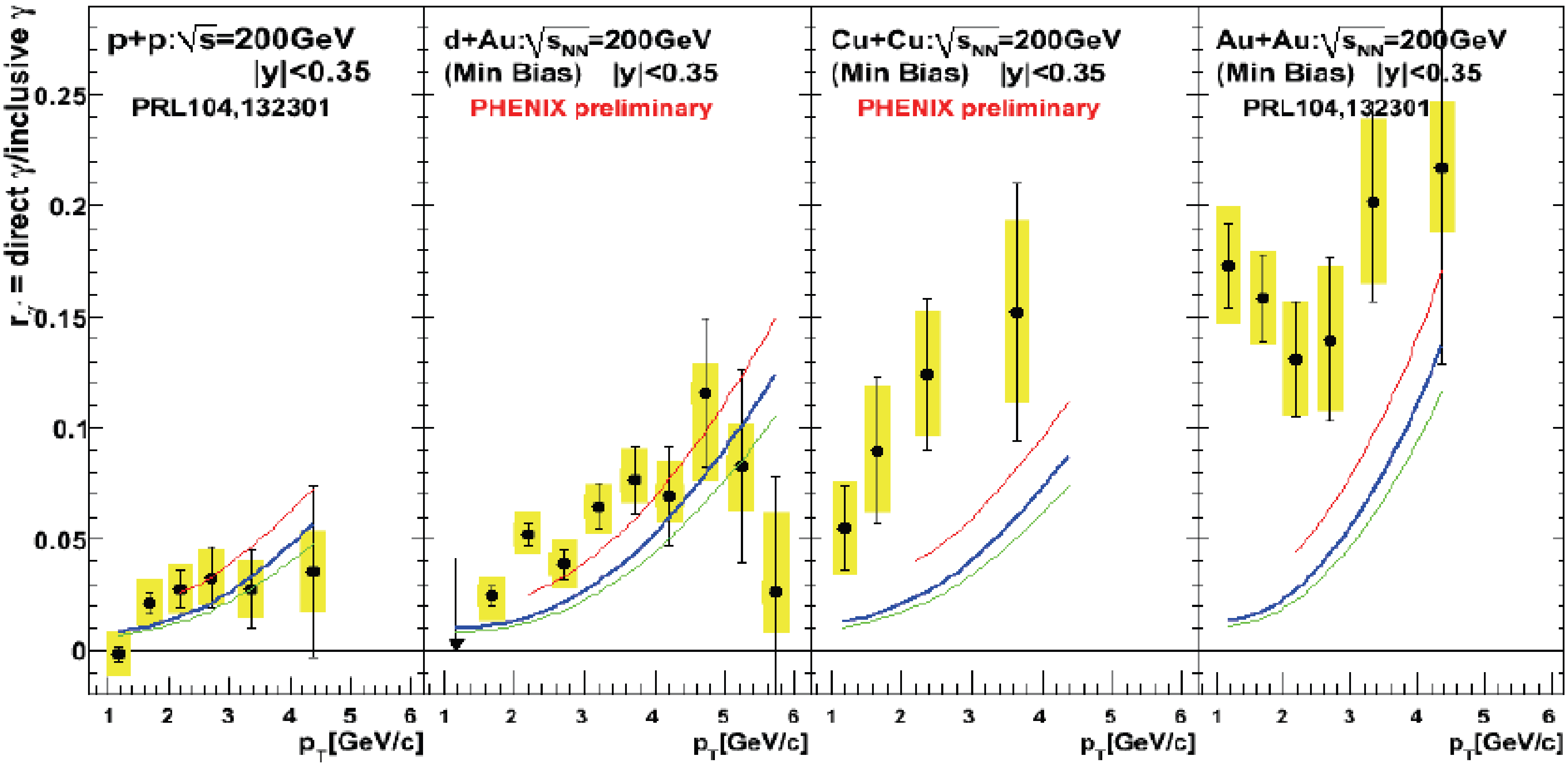


FIG. 2. The ratio of measured-to-calculated background photons as a function of transverse momentum for peripheral [part (a)] and central [part (b)] 158*A* GeV ^{208}Pb + ^{208}Pb collisions. The errors on the data points indicate the statistical errors only. The p_T dependent systematical errors are indicated by the shaded bands.

PRL 85 (2000) 3595

Unrealistic to get errors below 10% → need at least 20% signal

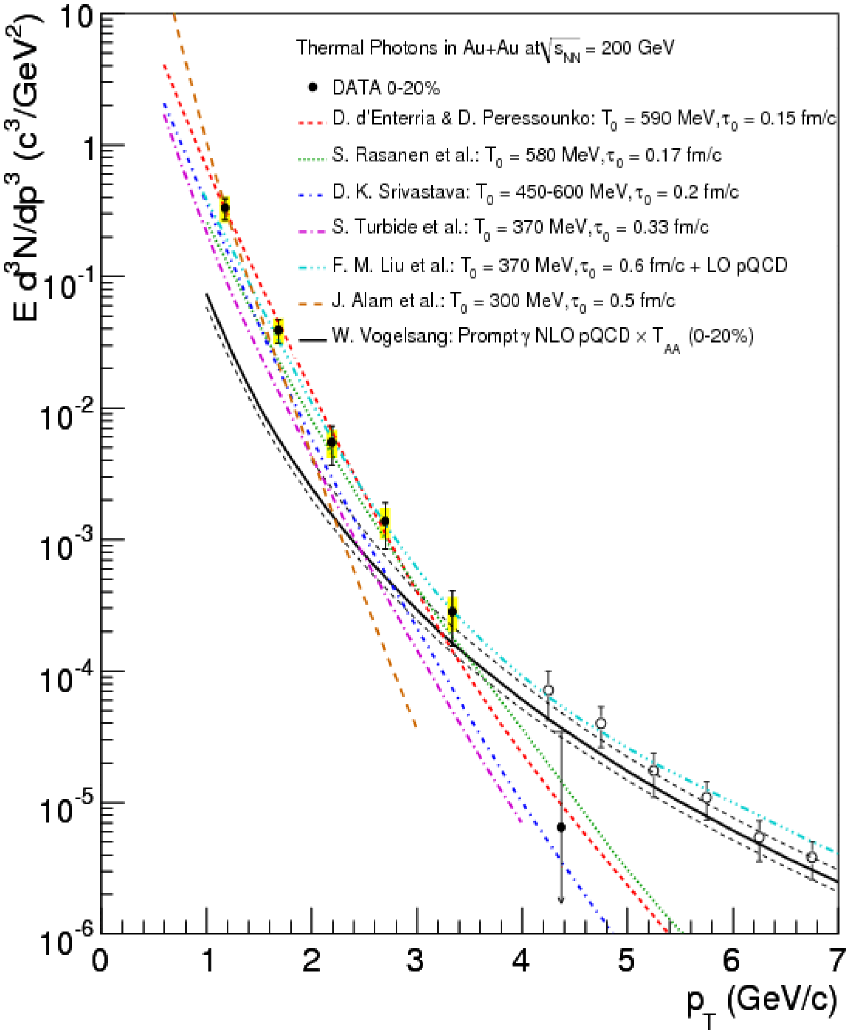
Thermal photons, PHENIX, via dielectrons

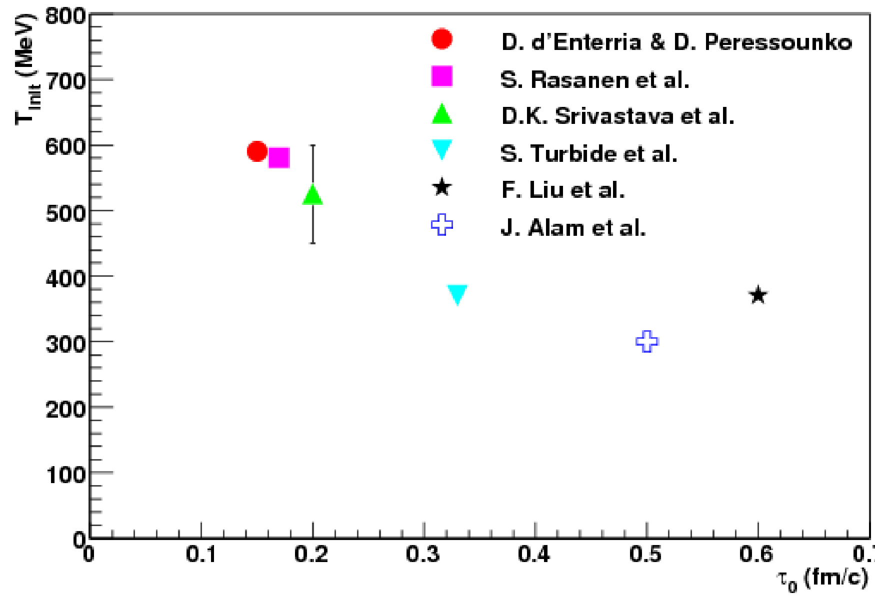


Better precision, but "starving for statistics"

Measurement with (external) conversion of real photons underway

Spectra alone: insufficient constraint

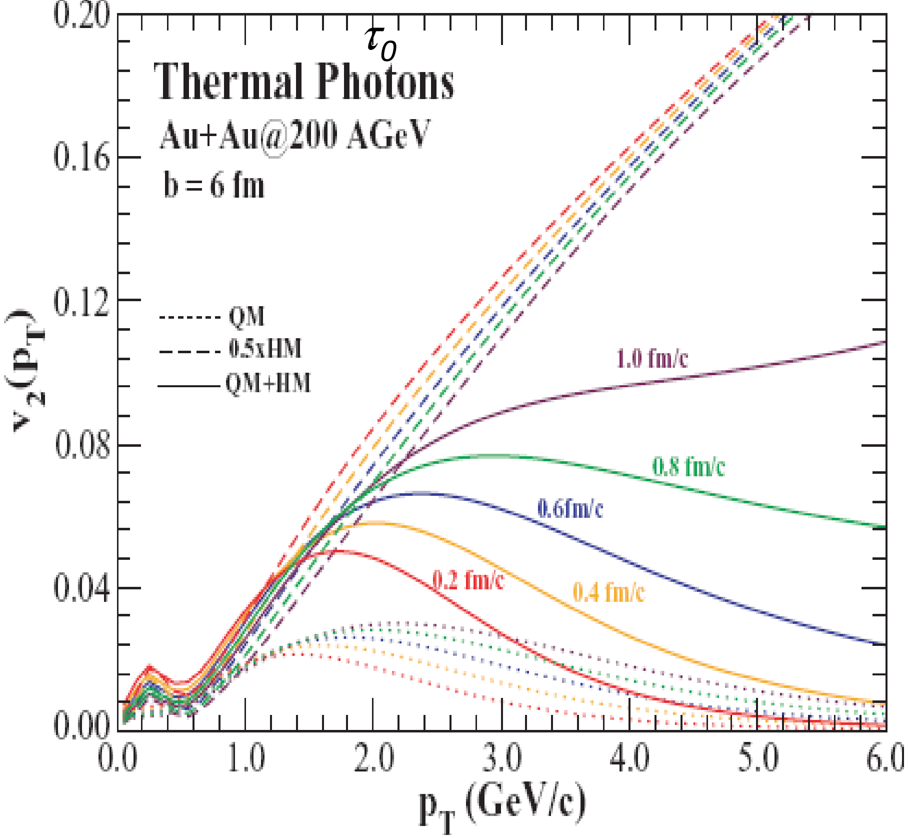




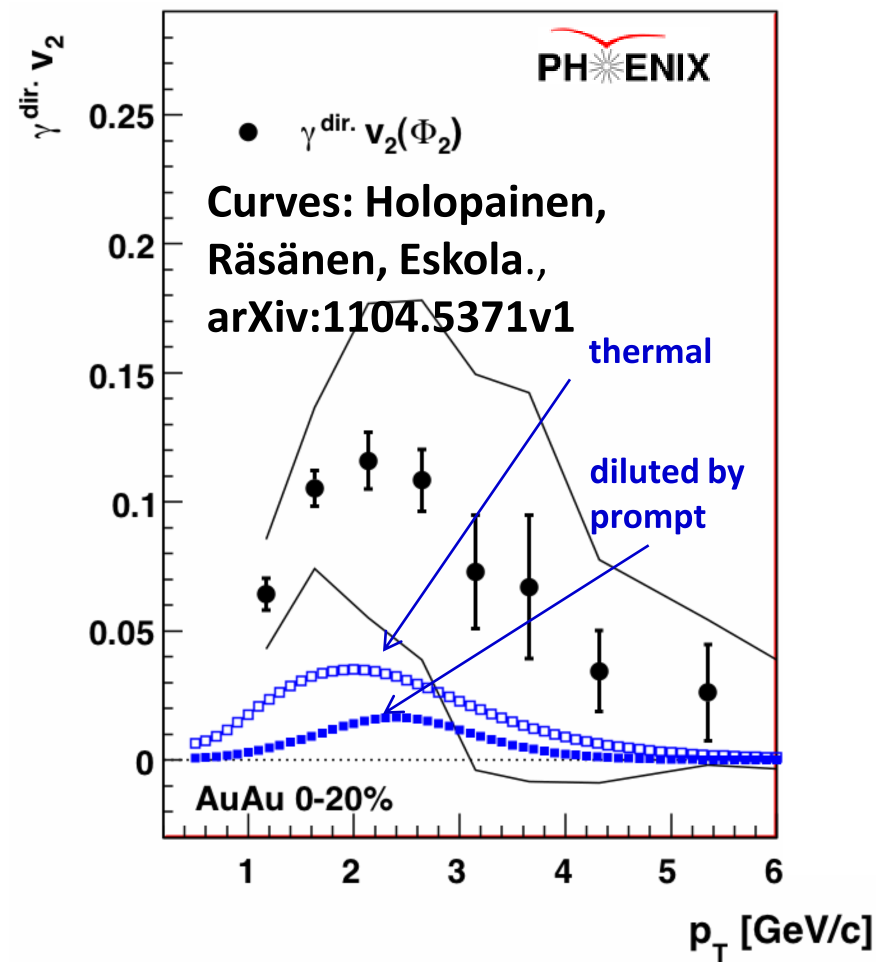
What would be needed to nail
T and/or τ down?
Also, the QGP/hadron ratio?

Thermal photon flow: theories vs data

Hydro after τ_0



Chatterjee, Srivastava PRC79, 021901 (2009)



Predictions: large measured values prefer hadronic sources

Is the “QGP window” shut?

PRC 84 (2011) 054906

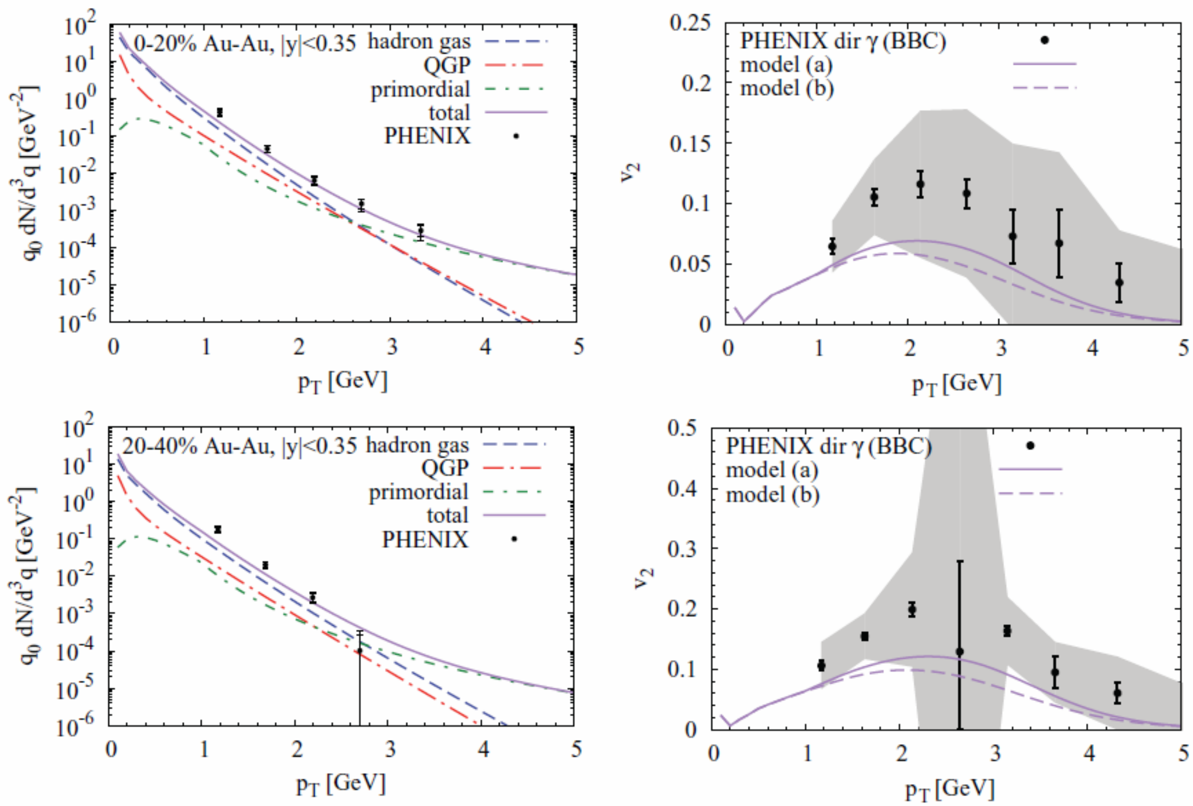


FIG. 5. (Color online) Comparison of our calculated direct-photon spectra (left panels) and their elliptic-flow coefficient (right panels) from an elliptically expanding fireball model with QGP and hadronic radiation, supplemented with primordial emission, to PHENIX data [7,11] in 0–20% (upper panels) and 20–40% (lower panels) central Au-Au($\sqrt{s} = 200A$ GeV) collisions. The error bars indicate the statistical and the gray band the systematical errors. Models (a) and (b) in the right panels refer to the use of the pQCD parametrization and the PHENIX fit for primordial production, respectively [in the left panels, only model (a) is displayed].

For a long time we thought (hoped) that there is a region where QGP radiation dominates. Is this not true anymore? And if not – is it a blow, or an opportunity?

Additional dimensions: a handle on time (phase)?

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Pair mass, the additional
degree of freedom
can make dielectrons sensitive
to time evolution

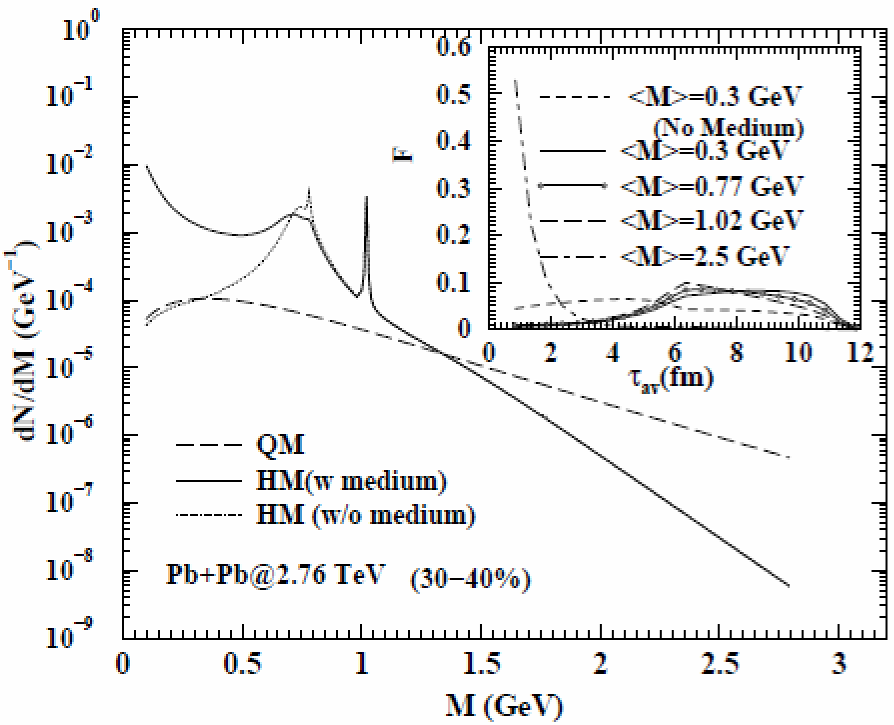


FIG. 1: Invariant mass distribution of lepton pairs from quark matter and hadronic matter (with and without medium effects). Inset: Fractional contribution of lepton pairs for various invariant mass windows as a function of average proper time (see text for details).

The PHENIX dielectron puzzle

Enhancement at low pair mass,
low transverse momentum

In Au + Au collisions, the data are consistent with the expectations from correlated $c\bar{c}$ production for $m_{ee} >$ 0.5 GeV/c^2. However, this interpretation is ambiguous, due to the interplay between possible two different medium effects: energy loss of charm quarks in the medium which would deplete the yield in the IMR, and QGP radiation, which would increase the yield in the IMR.

In the low mass region the Au + Au Min. Bias inclusive mass spectrum shows an enhancement by a factor of $4.7 \pm 0.4^{\text{stat}} \pm 1.5^{\text{syst}} \pm 0.9^{\text{model}}$ compared to the expectation from the hadronic cocktail. The enhancement is concentrated at low p_T ($p_T < 1$ GeV/c). The integrated yield increases faster with the centrality of the collisions than the number of participating nucleons.

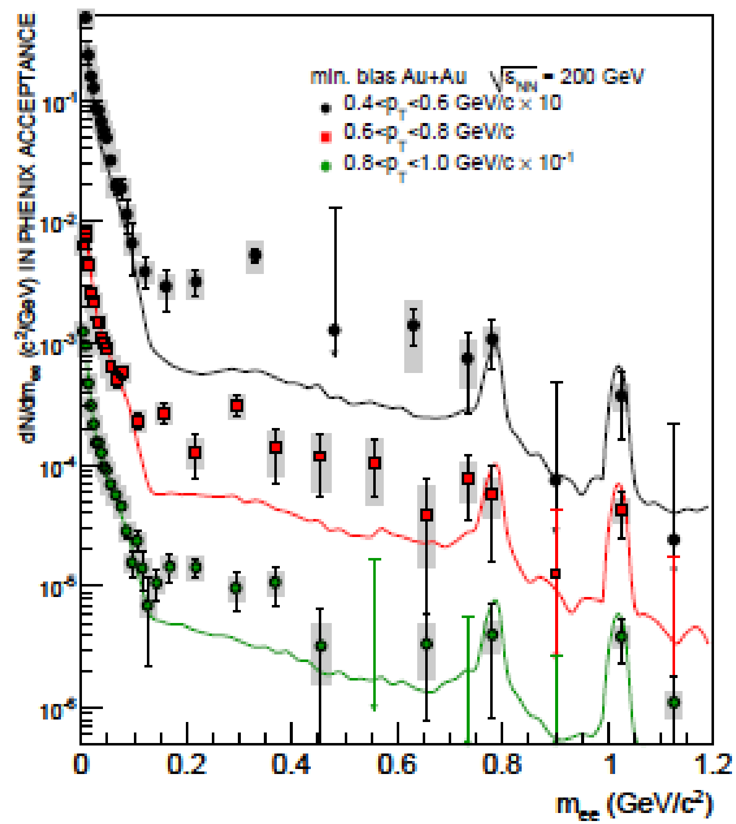


FIG. 35: (Color online) The e^+e^- pair invariant mass distributions in minimum bias Au + Au collisions for the low-p_T range. The solid curves represent the cocktail of hadronic sources (see Section IV) and include contribution from charm calculated by PYTHIA using the cross section from [46] scaled by N_{coll}.

The easiest and the hardest of all

Photon counting (left) and HBT (right)

Cerny, Lichard, Pisut, Z. Phys. C31, 163 (1986)

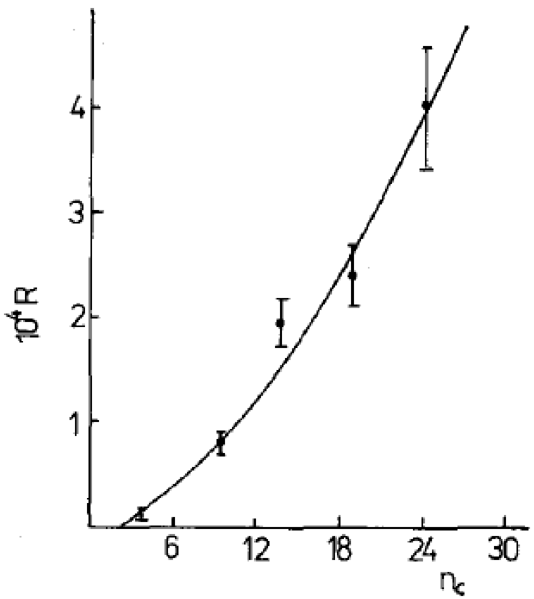
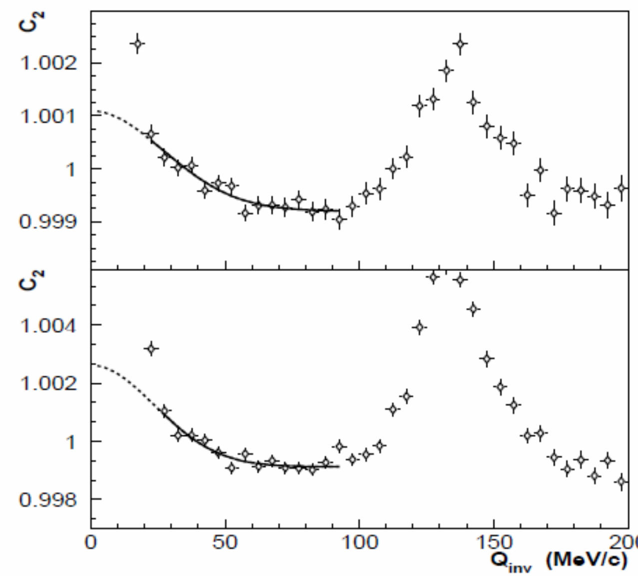
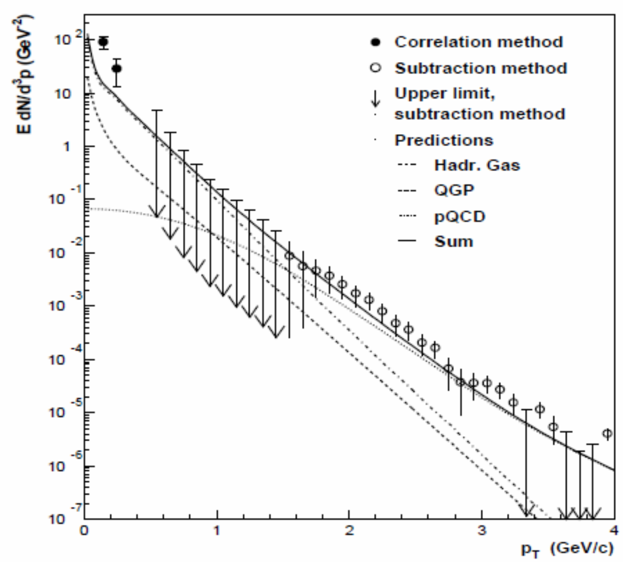


Fig. 1. The dependence of the ratio (R) of the mean number of dileptons per event on the total multiplicity n_c of associated charged hadrons at $\sqrt{s}=63$ GeV





Tried by WA98 (nucl-ex/0202012) and STAR (nucl-ex/0511026) didn't seem to go very far

WA98 – nucl-ex/0310022

Experimental issues

Good news: rates in the thermal region are very high (even for e.m. probes)
→ small acceptance **or** small branching ratio not a serious problem
(although still cannot have both small…)

Bad news: tremendous backgrounds both for photons and dileptons
building the "dream experiment" is unrealistic

My personal prejudices at this moment (would gladly abandon them!)
→ classic calorimetry is not a viable option in the thermal region
(elsewhere of course it is!)
→ real photons are best measured with well-controlled external conversion
→ dielectrons?

Summary - or plea

I strongly believe that thermal photons remain the clue to many properties of the QGP and extremely hot hadronic matter

If you believe it, too, please join an effort to come up with a viable plan

Theorists:
tell us, please, what observables and at what significance would be "decisive"

Experimentalists:
please dream within the limits of reality

Penetrating probes (like thermal photons and dileptons) are the most comprehensive "historians" of heavy ion collisions.
We just have to learn to read and decypher their message!